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To

RECOMMENDED GENERAL PROCEDURE FOR CUSTOMER CHECKING OF CAPACITANCE CALIBRATION ON BEC MODEL 74 AND 75 CAPACITANCE BRIDGES

MP MASTER
MA24753

RECOMMENDED GENERAL PROCEDURE FOR CUSTOMER CHECKING OF CAPACITANCE CALIBRATION ON BEC MODEL 74 AND 75 CAPACITANCE BRIDGES

SUMMARY:

Calibration checking should be done at 100 KC whenever possible.

It is suggested that the following sequence of tests be adhered to:

1. Preliminary "Quick-Checks".
2. Dial tracking on XI (1000 pf F.S.) range. (@ 100 KC)
3. Full scale accuracy on other XC ranges. (@ 100 KC)
4. (Optional) Check of additional points on other than XI range. (@ 100 KC)
5. 1 MC correlation. (On 75 series bridges)

EQUIPMENT REQUIRED:

1. BEC Model 75-2A 100 KC Oscillator/Detector Unit (not required for 74C).
2. BEC Model CS-100/1000 Three-Terminal (Direct) Capacitance Decade : 100 pf per step.
3. BEC Model CS-10 Direct Capacitance Standard (10 pf).
4. BEC Model CS-1 Direct Capacitance Standard (1 pf).
5. BEC Model CS-.1 Direct Capacitance Standard (0.1 pf).
6. 6 inch or shorter BNC Cables.

Additional Equipment Required for Step-ups:

7. BNC T Connectors.
8. Air Variable Capacitor mounted in (and insulated from) shield case fitted with BNC receptacles. See Figure 2 .

PRELIMINARY "QUICK-CHECK" SERIES

Before proceeding with calibration checks or adjustments, it is desirable to try to determine that the bridge to be checked does not have any easily detectable mechanical or electrical faults.

The following series of checks requires no auxiliary equipment. A bridge that passes these "Quick-Checks" is not guaranteed to be normal, but a normal bridge should pass without difficulty. For 75C, see its Instruction Book for a special version of "Quick-Checks" applying to it only.

a. Dial Stop (Mechanical Check)

(Checks the dial stop action and correctness of dial alignment with variable capacitor rotary position.) Rotate the CAPACITANCE dial until the stop is reached (at -50). The fiducial should be over the mark on the counter (outer) dial, and should coincide with 0 on the inner dial (within ± 2 small divisions).

b. Capacitance Zero (Electrical Check)

(Checks the setting of internal zero adjustments and general balancing of capacitance circuits at zero). Turn on and allow 5 minutes warmup. Turn the GROUNDED/DIRECT switch to DIRECT, the DIVIDE G/MULTIPLY R to 1K, and the MULTIPLY C to XI. Turn the OSCILLATOR LEVEL and SENSITIVITY controls full on. Set the CAPACITANCE and CONDUCTANCE dials at zero.

Balance the bridge with the C ZERO and R/G ZERO controls. Balance should be obtained with the COARSE C ZERO white dot or knob pointer near the top (near mid-rotation), and must not be near either electrical maximum or minimum.

Switch to GROUNDED and repeat the procedure.

Rotate the CAPACITANCE dial all the way to the upper stop*, observing that the meter indication rises and that there are no nulls at any points other than zero. The upper stop should act at approximately 1050 (within ± 5) dial pf.

* Reduce INDICATOR SENSITIVITY (if required) to keep meter reading on-scale.

c. CAPACITANCE Dial Backlash

(Checks for normal operation of the entire variable capacitor system, including the v.c. and its gearing and drive mechanisms.)

Set up as for (b) and balance the bridge. When the CAPACITANCE dial is turned from at least 10 dial pf off null into the null, the null should occur at the same dial point whether approached from a clockwise or counter-clockwise direction. If it differs by more than 1 small division, the backlash is excessive (it is still usable, however, if the same null point is always obtained when approached from the same direction).

d. Capacitance Sensitivity (Resolution)

(Checks for proper oscillator and detector functioning and gives a useful measure of resolution.)

Set up as for b, except use the X.001 MULTIPLY C range. Balance the bridge*, then adjust INDICATOR SENSITIVITY for a 5 μa. meter reading at best possible null (usually can leave full clockwise on 74's but must turn slightly counter-clockwise on 75A's or 75B's).

* On the 75B, the IND PEAK control should be tuned for maximum NULL INDICATOR meter reading after offsetting the CAPACITANCE dial for a reading of at least 50 μa.

When the CAPACITANCE dial is turned 1 dial pf in either direction from null, the increase in NULL INDICATOR meter reading should be approximately:

20 to 35 μa. on 74C's
30 to 50 μa. on 75A's
50 to 100 μa. on 75B's (and 75A-S4, 75A-S13)
15 to 30 μa. on 75C's (@ 100 KC)

e. Conductance Zeros

(Checks for proper relation between the dial zero and the electrical network and can detect some types of bridge input transformer mal-functioning.)

Switch DIVIDE G/MULTIPLY R to 1, MULTIPLY C to 1. Turn R/G ZERO control(s) with white dot or knob pointer up. Turn the CAPACITANCE dial to 0. Balance the bridge, using the CONDUCTANCE dial and COARSE and FINE C ZERO controls. Balance should occur within one small division of 0 on the CONDUCTANCE dial.

Leave the CONDUCTANCE dial at the above setting. Switch to each of the DIVIDE G/MULTIPLY R ranges and determine that the bridge can be balanced with relatively little offset of the R/G ZERO control(s) (within about ± 1 hour of the intial 12 o'clock setting).

DIAL TRACKING (XI MULTIPLY C RANGE)

The bridge to be checked should preferably have been operating for several hours prior to checking. If it is a 74C (100 KC) or 75C (5 to 500 KC) leave in cabinet for the dial tracking check. If a 75A or 75B (1 MC), remove from the cabinet and temporarily replace the 1 MC Oscillator/ Detector Unit with the BEC 75-2A 100 KC Unit(1). Return to cabinet. If it is a 75C, tune to 100 KC.

Switch to DIRECT, XI MULTIPLY C, XIK (1000) DIVIDE G/ MULTIPLY R, HI OSC LEVEL, and DC BIAS OFF (if the bridge has the DC bias feature). Turn the OSC LEVEL ADJUST control full clockwise, and the DC BIAS ADJUST control full counter-clockwise. Set INDICATOR SENSITIVITY at about 3 o'clock. For 75C only, tune to 100 KC operating frequency as detailed in the Instruction Book.

Connect the Three-Terminal 100/1000 pf Decade(2) to the HI and LO TEST coaxial receptacles, using convenient BNC patch cables (less than 1 ft. long). Switch the Decade to its zero position.

Zero balance the bridge. Adjust INDICATOR SENSITIVITY to achieve the desired resolution. Switch the Decade to each step and measure with the bridge. The measured values should be within the limits given in the following table. No adjustments should be attempted by the customer if the specified dial tracking is not met.

XI(1000 pf FS) Bridge Range

Decade Step	*Tolerance (pf)	Allowable Range of Dial Readings
100 pf	±0.65	99.35 - 100.65 dial pf
200	±1.0	199.0 - 201.0
300	±1.35	298.65 - 301.35
400	±1.7	398.3 - 401.7
500	±2.05	497.95 - 502.05
600	±2.4	597.6 - 602.4
700	±2.75	697.25 - 702.75
800	±3.1	796.9 - 803.1
900	±3.45	896.55 - 903.45
1000	±3.8	996.2 - 1003.8

* Based on the sum of Capacitance Bridge and Capacitance Standard tolerances. The bridge tolerance at 100 KC for all 74 and 75 series bridges is ±(0.25% + 0.2 pf). The Capacitance Standard tolerance is ±(0.1% + 0.1 pf).

FULL SCALE ACCURACY ON OTHER MULTIPLY C RANGES

A. X.1(100 pf F.S.) Range

Switch MULTIPLY C to X.1, set the Decade Standard at 0, and zero balance the bridge. Turn the decade to its 100 pf position and measure. The reading should fall within the following limits:

X.1(100 pf FS) Bridge Range

Decade Step	*Tolerance (pf)	Allowable Range of Dial Readings
100 pf	±0.47	995.3 to 1004.7 dial pf (99.53 to 100.47 pf)

* Based on the sum of the Capacitance Bridge and Capacitance Standard tolerances. On the X.1 range, at 100 KC at 100 pf, bridge tolerance is ±(0.25% + 0.02 pf). Standard tolerance is ±(0.1% + 0.1 pf).

If adjustment is required, proceed as follows:

1. 74C Series Bridges:

Remove the bridge from its cabinet, and with an insulated screwdriver, adjust the capacitor marked "X.1" to make the reading fall at or near 1000 on the CAPACITANCE dial. Recheck zero balance and repeat the reading to be sure the adjustment is correct.

2. 75A and 75B Series Bridges:

Remove the bridge from its cabinet. Before proceeding, note that the next step involves breaking of a seal that will void the BEC manufacturers' warranty. If authorized, break the seal on the rear cover plate of the bridge unit and remove the plate. AVOID DISTURBING WIRE OR COMPONENT POSITIONS IN THE BRIDGE UNIT. DO NOT TOUCH ANYTHING BUT THE SPECIFIED ADJUSTMENTS. With an insulated screwdriver adjust the capacitor marked "X.1" to make the reading fall at or near 1000 on the CAPACITANCE dial.

Recheck zero balance and repeat the reading to be sure the adjustment is correct.

3. 75C Bridges:

Follow the same procedure as for 75A and 75B except be sure that the operating frequency has been adjusted to 100 KC, following the procedure given in the 75C Instruction Book.

B. X.01(10 pf F.S.) Range

The procedure for this range is identical to that for the X.1 range except that the BEC Model CS-10(10 pf)(3) Standard replaces the 100 pf step of the Decade as reference, and that the "X.01" trimmer is used if adjustment is required. Note that bridge zero balancing must be done with both coaxial leads connected to the bridge, and the LO TEST one connected to the Standard.

The reading should fall within the following limits:

X.01 (10 pf F.S.) Bridge Range

CS-10 Standard	*Tolerance (pf)	Allowable Range of Dial Readings
10 pf	±0.05	995 to 1005 dial pf (9.95 to 10.05 pf)

* Based on the sum of the Capacitance Bridge and Capacitance Standard tolerances. On the X.01 range, at 100 KC, 10 pf bridge tolerance is ±(0.25% + 0.005 pf). Standard tolerance is ±(0.1% + 0.01 pf).

C. X.001 (1 pf F.S.) Range

On 74C, the 75A series bridges except 75A-S4 and 75A-S13, and on 75C, the procedure is identical to that for the X.01 range except that the BEC Model CS-1 (1 pf) standard (4) is used, and that the "X.001" adjustment is used if required.

On 75A-S4, 75A-S13, 75B and 75B-S8 it will be necessary to re-install the original 1 MC Oscillator/Detector unit in the bridge to obtain adequate resolution for accurate checkout of this range. After re-installing the 1 MC Unit proceed as before, except being sure to properly set the IND PEAK control during zero balancing.

On all bridges, the reading should fall within the following limits:

X.001 (1 pf F.S.) Bridge Range

CS-1 Standard	*Tolerance (pf)	Allowable Range of Dial Readings
1 pf	±0.0085	991.5 to 1008.5 dial pf (.9915 to 1.0085 pf)

* Based on the sum of the Capacitance Bridge and the Capacitance Standard tolerances. On the X.001 range, at 1 pf, the bridge tolerance is ±(0.25% + 0.001 pf). Standard tolerance is ±(0.1% + 0.004 pf)

D. X.0001 (.1 pf F.S.) Range /75B and 75B-S8 only/

Procedure for this range is identical to that for the 75B bridges on the X.001 range, except for use of the BEC Model CS-.1 (0.1 pf) Standard (5) and the "X.0001" adjustment. On this range there is some effect on calibration by replacing the rear cover plate of the bridge. A suggested procedure is to set the adjustment so that the Standard reads about 6 dial pf low. Replacement of the rear plate should raise the reading to or near nominal.

Readings should fall within the following limits:

X.0001 (0.1 pf F.S.) Bridge Range

CS-.1 Standard	* Tolerance (pf)	Allowable Range of Dial Readings
0.1 pf	±.00275	972.5 to 1027.5 $\frac{\text{dial}}{\text{pf}}$ (0.09725 to 0.10275 pf)

* Based on the sum of the Capacitance Bridge and the Capacitance Standard tolerances. On the X.0001 range at 0.1 pf the bridge tolerance is ±(2% + 0.00005 pf). Standard tolerance is ±(0.3% + 0.0004 pf).

"STEP-UP" PROCEDURE: CHECKING ADDITIONAL POINTS ON ANY CAPACITANCE RANGE

A. General Principle

Basically this involves reading a standard, C_S, on the bridge, then disconnecting it and substituting a variable capacitor, C_X, which is adjusted to restore the bridge balance. Next C_S and C_X are both connected in parallel to the bridge and read, thus giving a dial calibration point for 2 times C_S. Again disconnecting C_S and restoring bridge balance by re-setting C_X, then re-connecting C_S and reading, gives a dial calibration at 3 times C_S. This process is repeated until all the desired dial calibration points have been obtained.

Extension of this method to include coverage of all capacitance ranges of the bridge, and to give as many check points on the dial as desired is entirely feasible.

B. Restrictions and Precautions

The step-up technique is ideally suited for use at 100 KC or below, but becomes of restricted usefulness at higher frequencies.

At 1 MC the effects of series inductance make step-ups on the X1 (0 to 1000 pf) capacitance range possible, but quite difficult to do without introducing appreciable errors. In general, it is preferable to perform the step-ups at 100 KC; then to compare readings made at 1 MC. To insure accuracy when doing step-ups proper connection and measurement techniques for the bridge and the standards should be followed exactly. See Figure 2 for recommended connections.

C. Checking X.1 Capacitance Range

First connect up as shown in Figure 2 . The bridge should have been on for at least 5 hours, and all other parts of the set-up should be at room temperature (preferably 25°C). Set the bridge on DIRECT, X.1 (100 pf full scale) MULTIPLY CAPACITANCE range, X100 or X1000 DIVIDE G/MULTIPLY R range. With the CAPACITANCE dial at zero, balance the bridge using the CONDUCTANCE dial and the COARSE and FINE

capacitance zero controls. (All of the coaxial leads should be left connected to the bridge, and leads (1) and (3) to the standard and variable, throughout the following step-up series).

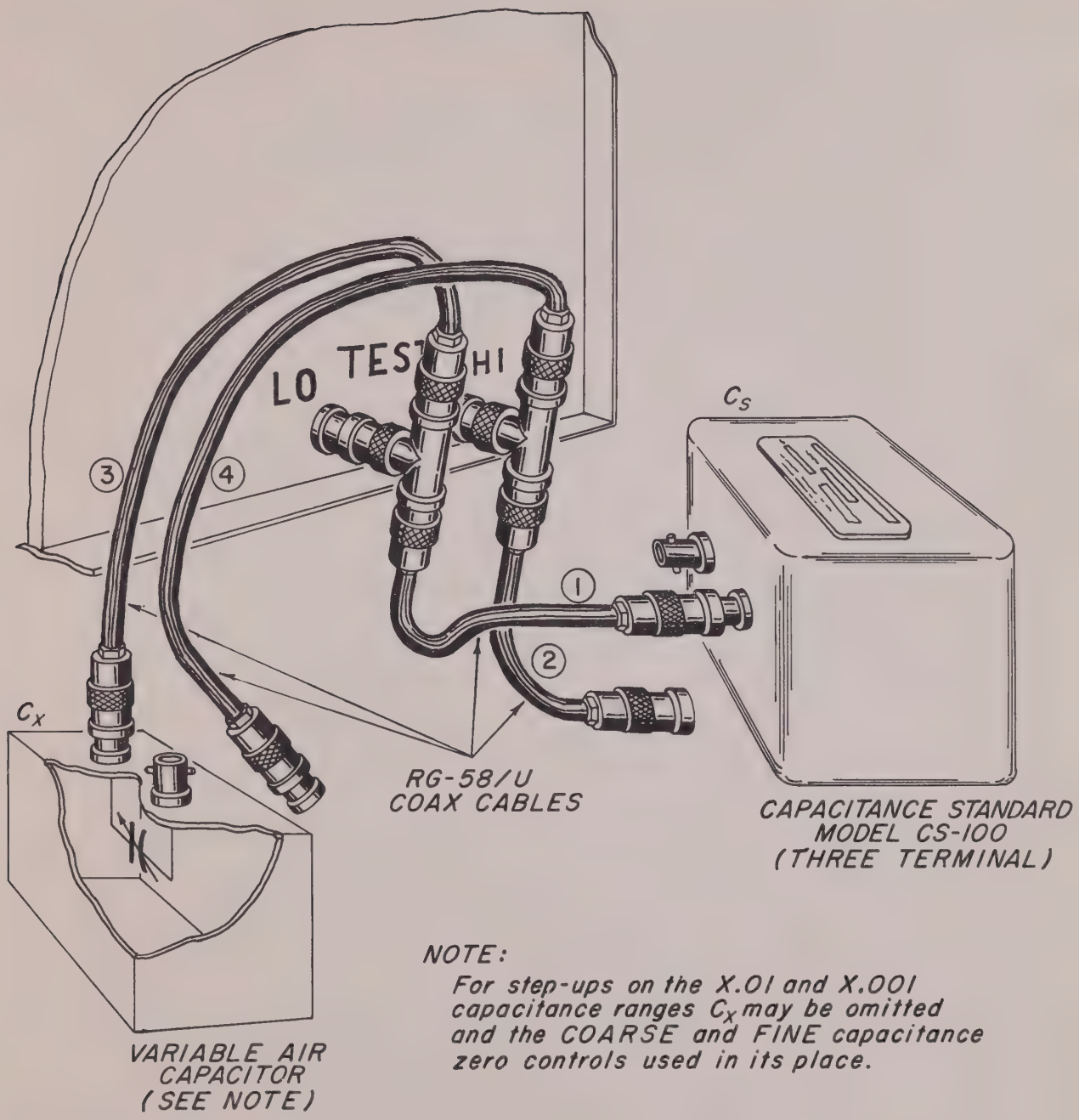
Connect lead (2) to the CS-10 standard (C_S) and read its capacitance on the bridge. Record. Disconnect lead (2) from the capacitance standard and connect lead (4) to the variable (C_X). Without touching the bridge capacitance controls adjust the variable C_X and the CONDUCTANCE dial to restore the null reading. Re-connect lead (2) to the standard and read the capacitance of $C_S + C_X$(2 times C_S). Record. Repeat the same procedure to obtain readings at 3 times C_S, 4 times C_S through 10 times C_S.

D. Other Capacitance Ranges

Other ranges can be checked similarly, using a CS-___ Capacitance Standard having a nominal value of 1/10th of full scale on the range to be checked.

MULTIPLY C RANGE	FULL SCALE CAPACITANCE (pf)	CS-___ STANDARD
X1	1000	CS-100
X.1	100	CS- 10
X.01	10	CS- 1
X.001	1	CS- .1
X.0001	0.1	CS- .01

When performing step-ups on the X.01, X.001 and X.0001 Capacitance ranges, the bridge COARSE and FINE C ZERO controls may be used in place of (or in conjunction with) the air variable C_X.



CONNECTIONS FOR STEP-UP MEASUREMENTS

Figure 2

(830,109A)

1 MC CORRELATION (ON 75 SERIES BRIDGES)

Except above about 100 pf and below about 1 pf, readings of the Capacitance Standards should be nearly the same at 1 MC as at 100 KC.

There are two major causes for the reading differences: series inductance, and shunt capacitance. Each will be discussed separately.

1. Effects of Series Inductance

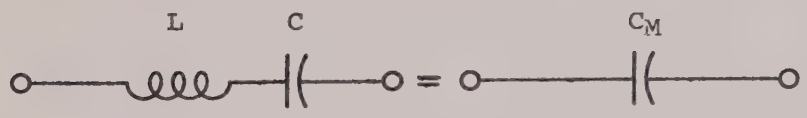
Reading differences on the X1 capacitance range are caused by series inductance. For example at 1 MC, a 1000 pf capacitor connected by 3 foot RG-58/U coaxial cables to an accurate bridge will measure about 1021 pf. At 100 KC the same capacitor with the same cables will read about 1000.25 pf. The nearly 100 times increase in error at 1 MC as compared to 100 KC neatly points up the problem; namely that when making measurements of capacitors larger than about 50 pf at 1 MC the error due to series inductance cannot be ignored for accurate measurements.

As shown in Figure 5, when the contribution of the series inductance is small, the measured capacitance can be shown to be equal to $(C + \omega^2 LC^2)$ where C is the true capacitance exclusive of the effect of inductance, and L the effective series inductance. The error thus varies as the square of the test frequency and the capacitance, but is proportional to the inductance.

Figure 6 expresses the inductance error in terms of % per foot of RG-58/U coaxial cables for the entire frequency and capacitance spans normally useful.

Appendix B "The USE OF CAPACITANCE STANDARDS LARGER THAN 100 pf FOR CHECKING CAPACITANCE ACCURACY ON THE X1 CAPACITANCE RANGE OF THE 75A AT FREQUENCIES ABOVE 100 KC" gives a detailed treatment of this area.

ERROR IN MEASURED CAPACITANCE DUE TO SERIES INDUCTANCE



$$C_M = \frac{C}{1 - \omega^2 LC}$$

and when $\omega^2 LC$ is small compared to 1,

$$C_M \approx C(1 + \omega^2 LC)$$

$$\approx C + (\omega^2 LC^2)$$

For example at 1 Mc, with L = 1 μh and C = 1000 pf,

(C in pf, L in μh, F in Mc)

$$C_M \approx 1000 \times 10^{-6} + \sqrt{(6.28 \times 1)^2 \times 1 \times (1000 \times 10^{-6})^2}$$

$$\approx 1039.4 \text{ pf}$$

at 100 Kc with the same constants,

$$C_M \approx 1000 \times 10^{-6} + \sqrt{(6.28 \times 0.1)^2 \times 1 \times (1000 \times 10^{-6})^2}$$

$$\approx 1000.394 \text{ pf}$$

Fig. 5

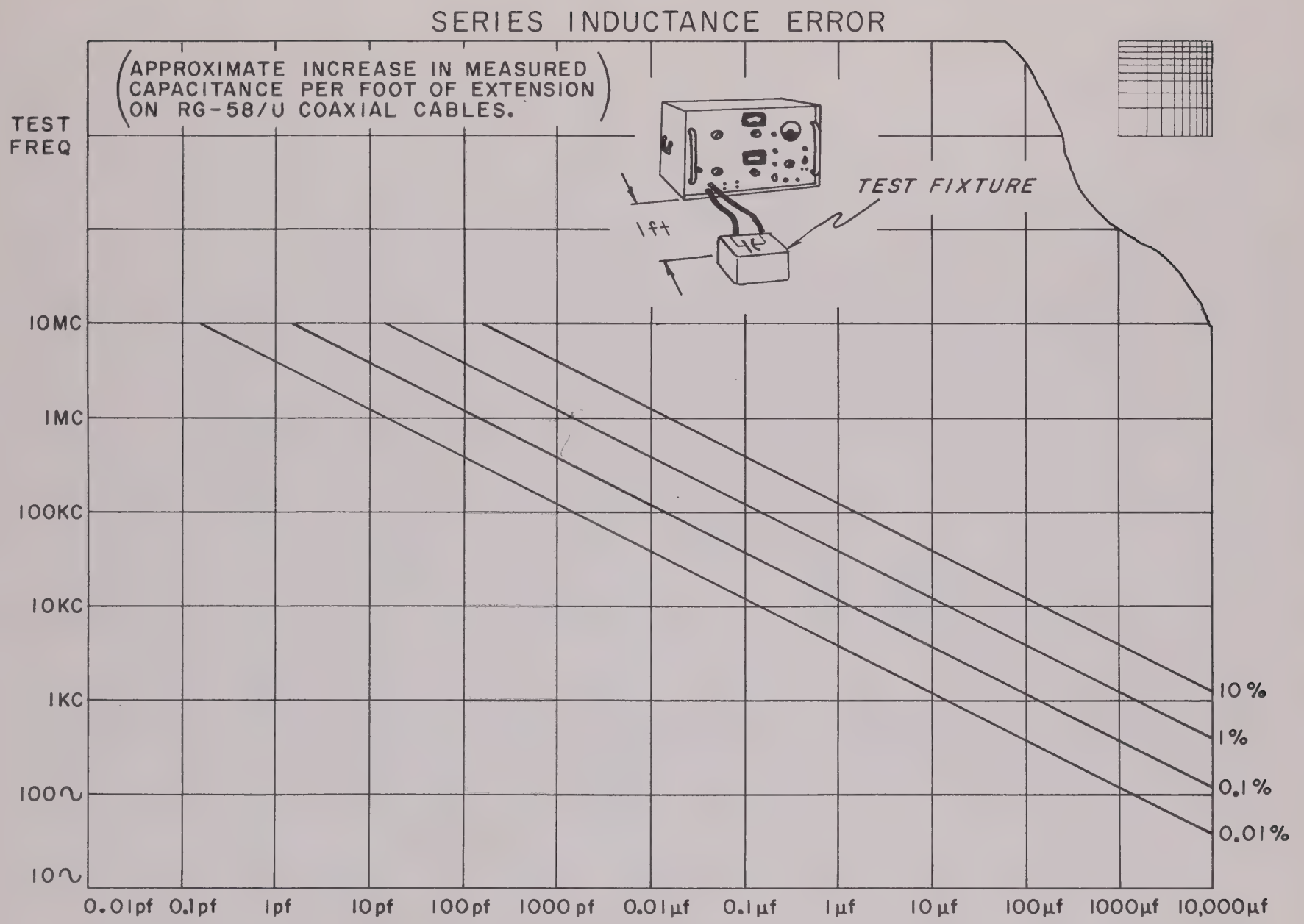

SERIES INDUCTANCE ERROR
(APPROXIMATE INCREASE IN MEASURED CAPACITANCE PER FOOT OF EXTENSION ON RG-58/U COAXIAL CABLES.)
TEST FREQ
TEST FIXTURE
1ft
10MC
1MC
100KC
10KC
1KC
100Ω
10Ω
10%
1%
0.1%
0.01%
0.01pf
0.1pf
1pf
10pf
100pf
1000pf
0.01μf
0.1μf
1μf
10μf
100μf
1000μf
10,000μf
CAPACITANCE

Fig 6

The table below gives a typical set of readings for a CS-100/1000 pf Decade Standard at 100 KC and at 1 MC, using 4-1/2 inch RG-58/U coaxial cables between the Standard and 75A bridge.

CS-100/1000		Readings (pf)	
Step	Nominal C (pf)	@ 100 KC	@ 1 MC
1	100	100.0	99.8
2	200	199.8	199.4
3	300	299.6	299.4
4	400	399.7	400.0
5	500	500.0	500.9
6	600	600.0	601.7
7	700	699.7	702.3
8	800	799.6	803.4
9	900	899.6	904.6
10	1000	1000.1	1006.9

?. Effects of Shunt Capacitance

Below about 1 pf the reading differences result from the effects of shunt capacitances.

An ideal Standard - one having a simple two terminal element and no shunt capacitance to ground - when connected to the bridge by cables short enough to have negligible capacitance will read the same at 1 MC as at 100 KC.

However, practical standards do have some shunt capacitance, hence cannot be thought of as producing no error.

Generally speaking, a fixed combination of shunting capacitance will produce a fixed pf error. Our CS-____ Standards are made with as low a shunt C as practical and can be relied on within their guaranteed tolerance. However, some small differences in readings between 100 KC and 1 MC are to be expected.

An Instruction Book for the Model CS-____ Standards has been included as supplementary information.

APPENDIX B

THE USE OF CAPACITANCE STANDARDS LARGER THAN 100 pf FOR CHECKING CAPACITANCE ACCURACY ON THE X1 CAPACITANCE RANGE OF THE 75A AT FREQUENCIES ABOVE 100 KC.

Introduction

At 1 Mc lead inductance effects become the limiting factor in making accurate capacitance measurements above approximately 100 pf. This paper offers specific suggestions for minimizing errors from this source.

In the design of the 75A great care was taken to minimize internal inductance, with the final design having less than 0.25% error in reading between 100 and 1000 pf without the use of a correction chart, provided the test is connected directly at the HI and LO TEST binding posts or directly at the centers of the TEST coaxial receptacles. The internal inductance errors may be further minimized by applying the corrections given in Table 1.

TABLE 1

(FROM 75A CAPACITANCE BRIDGE INSTRUCTION BOOK)

CORRECTION AT 1 MC FOR INTERNAL INDUCTANCE: X1 CAPACITANCE RANGE ONLY

CAPACITANCE DIAL READING (pf)	50	100	200	300	400	500	600	700	800	900	1000
ADJUST READING BY ADDING: (pf)	+.15	+.28	+.42	+.55	+.52	+.41	+.26	-.0	-.4	-.8	-1.2

Typical test results for a setup using a 75A, RG-58/U coaxial leads, and type CS-___ Capacitance Standards are given in Table 2.

Table 2

CS-__ Three-Terminal Capacitance Standard	Nameplate Value (pf)	75A CAPACITANCE READINGS USING RG-58/U COAXIAL CABLES					
		Cable Length 3-1/2 inches			Cable Length 9-1/2 inches		
		@ 100KC	@465KC	@ 1MC	@ 100KC	@ 465KC	@ 1 MC
CS-1000	1000.4	1000.1	1001.0	1003.9	1000.1	1001.7	1007.4
CS-750	743.9	743.8	744.05	745.4	743.8	744.6	747.4
CS-500	499.7	499.8	499.8	500.05	499.8	500.05	501.0
CS-300	299.7	299.85	299.8	299.6	299.85	299.9	300.0
CS-100	100.00	99.75	99.64	99.45	99.75	99.64	99.51

The comparative data in Table 2 for measurements made using 3-1/2 inch and 9-1/2 inch RG-58/U coaxial leads shows that at 1 MC it is impossible to measure a 1000 pf standard without incurring lead inductance errors. Each inch of increase in the length of the cables is shown to cause a 0.6 pf (0.06%) increase in the reading.

Table 3 interprets the data in Table 2 in terms of the increase in capacitance reading per inch and per foot of cable extensions. (See also Graph 1 of APPENDIX A in the 75A Instruction Book).

TABLE 3

Value of Capacitance Standard	INCREASE IN CAPACITANCE READING DUE TO INDUCTANCE OF RG-58/U COAXIAL CABLES.				
	At 1 MC		At 465 KC		At 100 KC
	Per ft. of cable	Per inch of cable	Per ft. of cable	Per inch of cable	
1000 pf	7 pf	0.58 pf	1.4 pf	0.12 pf	(Negligible error - no correction required)
750 pf	4 pf	0.33 pf	1.1 pf	0.09 pf	
500 pf	1.9 pf	0.16 pf	0.5 pf	0.04 pf	
300 pf	0.8 pf	0.066 pf	0.2 pf	0.017 pf	
100 pf	0.1 pf	-	-	-	
(Subtract to Correct)					

To Summarize:

1. The effects of lead inductance inside the 75A are small enough that at 1 MC specified accuracy is met without using corrections - provided the capacitor to be measured is connected directly at the HI and LO TEST binding posts or TEST coaxial receptacles. If greater accuracy is required, apply the corrections given in Table 1 to correct for the internal inductance effects.

2. The capacitance accuracy on the X1 range of the 75A should preferably be checked at 100 KC.

3. For capacitance measurements at 1 MC above 100 pf, correction must be made for the effects of the coaxial leads used between the test and the bridge, and may be figured from Table 3.

An Example:

A 75A is to have its capacitance accuracy checked on the X1 Capacitance range at 1 MC, using 100, 500 and 1000 pf type CS-__ Capacitance Standards connected to the bridge with 6 inch RG-58/U coaxial cables.

If no 100 KC Oscillator/Detector unit is available, a fairly accurate check can still be made by measuring the Standards at 1 MC, and applying both the corrections from Table 1 and Table 3 of this paper. The corrected readings should fall well within the bridge guarantee specifications.

(1) Standard: CS-___	"100"	"500"	"1000"
(2) Certified (Nameplate) Value of Standard	100.01 pf	500.26 pf	1000.4 pf
(3) Reading on 75A with 6" RG-58/U Coax. leads	99.8 pf	500.7 pf	1005.4 pf
(4) Correction from Table 1	+.28 pf	+.41 pf	-1.2 pf
(5) Correction from Table 3	-.05 pf	-.95 pf	-3.5 pf
(6) Net correction (4) + (5)	+.23 pf	-.54 pf	-4.7 pf
(7) Corrected reading (3) + (6)	100.03 pf	500.16 pf	1000.7 pf
(8) Bridge Calibr. Error (7) vs. (2)	+.02 pf	-.1 pf	+.3 pf
(9) Guarantee Tolerance (± 0.25 % +0.5 pf on X1 Range)	+0.75 pf	±1.75 pf	±3.0 pf

MP MASTER
MA24753